2.0 Historical Overview of Activities at Portsmouth

This section contains an overview of historical Plant activities at PORTS, presented chronologically within a series of functional areas, identifying key Plant conditions, operations, and practices. This section also summarizes the actual or potential effects of these conditions, operations, and practices on the safety and health of workers and the public, as well as on the environment. Sections 2.2 and 2.3 describe the historical hazards at PORTS; past operational and maintenance activities; practices used to identify, monitor, and control these hazards; and the effectiveness of these practices. Section 2.4 discusses unusual events and accidents. Sections 2.5 through 2.7 describe past practices in worker safety and health, waste management, and air and water emission control at PORTS and their effectiveness in mitigating impacts to the public and the environment. Section 2.8 reviews historical management and oversight practices and discusses employee relations.

2.1 Background

In July 1952, funds were designated for expansion of the domestic gaseous diffusion program, including additions to the gaseous diffusion plant at Oak Ridge, development of a new plant at Paducah, Kentucky, and construction of new \$1.2 billion plant at a site to be selected later. In August 1952, the U.S. Atomic Energy Commission (AEC) announced that a 4,000-acre tract of land near the Scioto River in Pike County, Ohio, would be the location of the new gaseous diffusion plant. Selection of this site was based on the availability of sufficient acreage of relatively flat terrain, significant amounts of electrical power, a dependable water source, local labor supply, and suitable transportation systems. Construction of the Portsmouth Plant was completed in March 1956, six months ahead of schedule and more than \$460 million under budget. The peak construction period was in 1954, when 22,500 workers were on site.

Major Facilities at PORTS

- *X-330, X-333, and X-326 – Gaseous Diffusion Process Buildings – 1954 to present*
- *X-344 – UF_6 Feed Manufacturing Plant – 1958 to 1962*
- *X-300 – Central Control Building – 1954 to present*
- *X-342, X-343 – Feed Facilities – 1954 to present*
- *X-705E – Oxide Conversion Plant – 1957 to 1978*
- *X-705 – Decontamination and Cleaning Building – 1954 to present*
- *X-700 – Maintenance Building – 1954 to present*
- *X-720 – Compressor Shop – 1954 to present*
- *X-334A – Transfer and Sampling Facility – 1975 to present*
- *X-342 – Fluorine Generation Facility – 1954 to present*

The Goodyear Tire & Rubber Company was named as the original management contractor. Goodyear Atomic Corporation was established as a wholly owned subsidiary of Goodyear Tire & Rubber for the purposes of managing and operating the Portsmouth Gaseous Diffusion Plant. Goodyear Atomic Corporation operated PORTS for the AEC and its successor agencies, the Energy Research and Development Administration (ERDA) and DOE, until Goodyear was replaced in 1986 by Martin Marietta Energy Systems, Inc., following Goodyear Atomic Corporation's decision not to participate in the rebid of the contract.

2.2 Operations

The first production cells went on line in September 1954, and the first product was withdrawn in October 1954. The purpose of the gaseous diffusion plant has been and continues to be the enrichment of uranium, initially for military applications and subsequently for commercial reactor fuel. PORTS enriched the feed material in the form of UF_6 gas to assays up to more than 97 percent uranium-235. The enriched product from PORTS was sent to other DOE sites and fuel fabricators. Most UF_6 feed material came from Paducah, K-25, the PORTS feed manufacturing plant, and commercial customers. From 1958 through 1962, some of the PORTS UF_6 feed material was produced from uranium tetrafluoride or UF_4 (called "green salt") in the X-344 Feed Manufacturing Plant. In addition, from 1957 to 1978 a small amount UF_6 feed was produced in the Oxide Conversion facility in X-705E.

The main process buildings at PORTS (X-330, X-333, and X-326) contain the "cascades," which are a series of compressor, heat exchanger, control valve and motor, converter stages, and supporting piping arranged in stages, cells, and units that progressively enrich the UF_6 feed. Enrichment occurs as the UF_6 passes through barriers in the converters that allow isotopes of lower molecular weight to pass through and is slightly enriched in uranium-235 by each stage from the feed point to the top of the cascade. Conversely, the feed is depleted in uranium-235 assay from the feed point to the bottom of the cascade. At PORTS, UF_6 could be fed from product and withdrawn from cylinders at any part of the cascades, using mobile units. Later, fixed feed facilities were installed in X-342A and X-343 using autoclaves to heat the cylinders and feed UF_6 gas to the cascade. The mobile withdrawal facilities have not been used since 1991. The product withdrawal stations are located in X-333 and X-326 and the tails withdrawal station in X-330. High-assay product is withdrawn at the X-326 product withdrawal station, intermediate-assay product at the extended range product (ERP) station in X-326, and lower-assay material in X-333. Both the enriched product and the depleted tails are fed into cylinders and allowed to cool until solid; the product is shipped to customers, and the depleted material is either re-fed to the cascade or stored on site.

The process building work areas were physically hot, but generally clean and uncontaminated, except when cascade equipment was opened due to equipment failure or for maintenance or modification. The process buildings were also the source of many UF_6 releases during connection and disconnection of sample bottles and feed and product cylinders, and from broken instrument lines. Generally, in the cascades, the use of respirators was only specified for maintenance or non-routine work activities. For feed, withdrawal, and sampling (activities where connections to the process systems are made and broken) additional personal protective equipment requirements and precautions were specified. These activities accounted for the majority of UF_6 releases and personnel exposures to process gas and hydrofluoric acid (HF) at PORTS. In 1974, as releases continued in these work tasks with the resulting spread of contamination, releases to the environment, and worker exposures, OR pressured Goodyear Atomic Corporation to conduct a focused review to identify ways to minimize releases from cascade operations. Subsequently, operational and procedural requirements were strengthened, cylinder connection hardware was redesigned, more frequent inspections and tests were conducted, ventilation systems were installed, and additional respirator use was specified. Although performance improved, compliance with operations procedures and the wearing of personal protective equipment remained inconsistent, and accidental releases still occurred. Cascade operations also routinely released small amounts of UF_6 to the environment through process system vents as a result of an operation called "jetting." Jetting involved venting of residual purge products from the evacuation of process piping, assisted by compressed air, in preparation for maintenance or replacement of components. These process line vents, although constructed with various traps and monitoring devices, also provided easy pathways to the environment from inadvertent or intentional valve positioning errors or overloading of traps.

During early 1952, the AEC approved the enrichment processing of production reactor tails through the gaseous diffusion process, and feeding of reactor tails from Paducah product commenced at Portsmouth in 1955. In 1957, radiological surveys at the Paducah Plant found neptunium-237 in the enrichment cascade. Although the AEC recognized the potential for transuranic contamination of the cascades, it was not until a 1965 appraisal that OR identified a potential problem with transuranics and fission products in X-705E, and recommended studies to determine where they could concentrate in the process. Although records indicate that PORTS reviewed the potential problems posed by feeding reactor returns to the oxide conversion plant, detailed studies were not performed. Goodyear Atomic Corporation concluded that transuranics were not a significant radiological concern when compared to uranium, and tower ash (where transuranics were expected to concentrate) could be monitored to measure the existing hazard. However, this monitoring program was not implemented. PORTS was also aware of the presence of technetium on process equipment as early as 1962, but also assumed that transuranics and fission products would not be a significant hazard to workers. No special monitoring or personnel protection controls were established. This posture persisted until 1975, when sampling and analysis of media, including pond sludge and waste samples, identified technetium-99. In 1979, a release in the X-705 annex during disassembly of a converter resulted in the internal contamination of six workers with technetium levels as high as five times the Plant restriction levels (but not in excess of regulatory limits). In 1980, analysis of cascade deposits confirmed the presence of neptunium and plutonium in the process system. These data indicate that, while Goodyear Atomic Corporation management was aware of both transuranics and technetium contaminants from incoming feed materials, they failed to recognize or evaluate potential radiological problems resulting from their concentration in the cascade.

The X-344 feed manufacturing plant converted UF_4 to UF_6 by passing the powdered green salt through elemental fluorine gas in four reaction towers. UF_6 was withdrawn, filtered, solidified in cold traps, reheated and transferred to cylinders, and re-fed to the cascade. Excess F_2 was recovered, and unreacted material fell into collectors as ash. After cooldown and decay, the ash was recycled by blending it with the green salt being fed into the top of the towers. When the plant closed in 1962, residual ash from X-344 was transported to Paducah for processing and uranium recovery. Operating conditions in the plant buildings were harsh, especially in the tower areas: high temperatures, noise, dust, and smoke. Leaks and spills of green salt and ash presented continuing problems with surface and airborne contamination. However, no reactor-returns green salt was processed in this facility. Radiation levels were high near the fluorination towers and the ash receivers, where uranium daughter products tended to concentrate. Workers in the feed plant were constantly exposed to these hazards. Although respiratory protection was required by procedure for many “dirty” jobs in the feed plant, industrial hygiene and health physics department reports and OR assessments reflected poor compliance. A 1961 OR appraisal noted that, although procedures required respiratory protection, operators in the area were not masked and

Construction of X-344

did not have masks, and the supervisor stated that they did not normally wear masks in that area.

Oxide conversion work in X-705E likely presented the most hazardous radiological and chemical exposures to workers at PORTS. The original plant design was inefficient, and many health physics concerns with airborne and surface contamination resulted from manual handling of fine uranium oxide powder. In 1965, these problems prompted a new plant design in preparation for future oxide feed from recycled reactor fuel, which would involve handling transuranics and fission products. The old system was dismantled and removed, and the new system, with more automatic processes and glovebox enclosures, was installed in X-705E in 1967. In the new design, oxide powder, in the form of U_3O_8, was ground and fed into a fluorination reactor (several designs were used over the years of plant operation), and the UF_6 was withdrawn into cold traps, where it solidified. Cold traps were removed and heated, and the liquefied UF_6 was drained into cylinders for feeding to the cascade. However, safe operation and maintenance of the new system was also beset with airborne uranium contamination problems including burn-through of the fluorination tower, leakage from cold traps and product withdrawal, and breaches into the system. Although respirators were recommended by the health physics staff and required by some procedures in oxide conversion operations, compliance was again inconsistent. This inconsistency was identified in industrial hygiene and health physics inspection reports from the late 1960s stating that respirators were not worn and gloves were removed from gloveboxes for some work. In 1973, an OR inspection cited numerous radiological occurrences in X-705E, including high airborne contamination, eating and drinking in the contaminated cold trap room, numerous instances of workers not wearing required respiratory protection, and increasing lung burdens for chemical operators. In-vivo monitoring was performed on oxide conversion plant workers, and, in 1965, significant intakes of insoluble uranium were detected in at least two of these workers. These employees were put on permanent restriction and had measured lung burdens over 50 percent of allowable limits many years later. One worker still had a significant lung burden when he retired in 1985. Raw material for the oxide conversion facility was generated on site through uranium recovery operations or conversion of uranyl nitrate hexahydrate (UNH) from offsite sources, or came from oxides from commercial processors and government sources. Oxide conversion production was greatest from 1968 to 1977, when the plant generated 10,000 to 50,000 kilograms per year of uranium as UF_6.

The continual, and often extensive, maintenance and modification activities on contaminated process systems and the oxide conversion plant were supported by significant efforts to decontaminate and clean removed components in X-705. Large items were processed in an automated decontamination tunnel, where parts were sprayed with acid solutions several times, rinsed with water, and then hot-air dried. The acid solutions were recycled until uranium levels exceeded discard limits and were then processed to recover the uranium. Until the 1980s, rinse water was discharged through building drains; it now goes to the sanitary waste system. Fans exhaust air from the tunnel to the atmosphere through roof vents. In the early 1980s an annex was built onto X-705 to facilitate decontamination of potentially heavily contaminated cascade components, such as compressors and converters. Some smaller parts were also decontaminated by hand in the seal disassembly room. Airborne activity was high, and respirators were required until air-supplied hoods were installed in the disassembly room in the mid-1970s. Empty feed/product cylinders were washed out in the low-bay area of X-705 to remove heels. In the 1950s and 1960s, cylinder cleaning was done in an open area and rinse water went into building drains. In 1971, a closed and automated cleaning system was installed, where cleaning and rinse solutions were collected and processed through the uranium recovery system.

Smelter Activation

Due to the monetary and strategic value of uranium, a wide variety of liquid and solid wastes containing uranium were processed through a solvent extraction recovery process in X-705. These operations concentrated radioactive materials, including technetium and transuranic compounds, and posed airborne hazards from both concentrated liquids and oxide powder. The uranium oxide (U_3O_8) produced from the calciner at the end of the recovery process provided potential exposure to insoluble uranium and transuranics. Transuranics were a special problem in 1965, 1966, 1975, and 1976, when recycled foreign reactor feed in the form of UNH was converted to oxide in the calciner. Raffinate waste was initially discharged to an onsite ditch leading to the Scioto River. Later, the X-701B settling pond was constructed; this reduced offsite contaminated effluents but increased onsite soil and groundwater contamination. In 1984, new systems in X-705 were effective in removing heavy metals and reducing radioactive materials from the building effluents.

From 1961 through 1983, a smelter operated in X-744G, melting scrap aluminum primarily from compressor improvement programs and damaged compressors. Although material went through a decontamination process before being placed in the furnace, industrial hygiene and health physics surveys indicated potential problems with airborne contamination during loading, melting, unloading, and removal. Former industrial hygiene and health physics department personnel stated during interviews that uranium contamination tended to stay with the melted aluminum. Aluminum ingots were sold for unrestricted commercial reuse or were used to make replacement parts for cascade equipment.

Non-operations and maintenance (i.e., support) personnel working in PORTS facilities, including guards, janitors, and delivery personnel, were also exposed to Plant hazards, especially unplanned releases, “wisps,” “puffs,” and chemical spills. From

Plant startup until the early 1990s, protective force personnel were often posted in close proximity to workers who were wearing respirator protection, while guards were not. From the early 1980s until the mid-1990s, guard force personnel performed security drills without protective clothing in spaces that were radiologically and chemically contaminated, while workers in these same spaces generally used such protection.

2.3 Maintenance and Modifications

Maintenance and process system modification activities have resulted in much of the radiation exposure, airborne contamination, and releases of UF_6 experienced at PORTS. The gaseous diffusion cascades are large complexes with thousands of components, many operating at high speeds and temperatures. Maintenance and modifications on these systems and components often required opening of systems that contained UF_6, deposited uranium compounds, technetium, or other hazardous materials. Many components had to be removed from the cascade buildings and taken to shops for decontamination, repair, or replacement. Maintenance and decontamination activities involved many tasks that created more hazardous conditions and opportunities for releases and exposures to workers, including welding, cutting, grinding, decontamination, and pipe crawling to retrieve debris and perform maintenance. Maintenance personnel and chemical operators decontaminating, maintaining, and modifying equipment were regularly exposed to UF_6, HF, TCE and other solvents, PCB-contaminated oils, welding gases, mercury, and other toxic metals. Work techniques, engineering controls, procedural requirements for personal protective equipment use, and the quality and availability of personal protective equipment (principally respirators) improved through the years, but lack of compliance was a recurring problem.

Essentially from initial startup into the 1980s, some form of process modification was in progress, with the most comprehensive and longest campaign, performed between 1972 and 1983, called the cascade improvement program and cascade uprating program (CIP/CUP). These programs replaced or upgraded key cascade components, such as converters, compressors, transformers, and motors to increase diffusion process reliability, capacity and efficiency. Line management, specifically first-line supervision, was responsible for specifying and enforcing safety and health controls for workers performing maintenance and modification activities. The industrial hygiene and health physics department personnel performed routine surveys, monitoring of work areas, special surveys, and other activities as requested by workers or supervision. Recommendations for controls, including decontamination and personal protective equipment, were provided by industrial hygiene and health physics but were inconsistently implemented by workers and line management. Instrument technicians were exposed to mercury, UF_6, HF, and TCE, and in later years to technetium, when performing cleanout, decontamination, calibration, and replacement of process line instruments and chemical traps associated with line recorders.

2.4 Unusual Events and Accidents

During almost 50 years of operation there have been numerous operational or work related events that posed potential safety and health risks to workers and the public, and damage to the environment. Well over 400 releases of process gas or fluorine have been documented over the years, and many more minor releases occurred that may not have been documented and tabulated as events. The most frequent and notable unusual event was the release of UF_6 gas into work areas or the environment. These releases ranged from very small amounts (commonly referred to as puffs or wisps) that stayed within work enclosures or buildings, to significant amounts that escaped outside buildings, caused building evacuations, or resulted in HF burns or uranium intakes requiring bioassay or medical attention for dozens of workers. Plant reports reflect approximately 90 UF_6 releases in excess of 10 pounds of uranium. The largest release was in 1978, when over 13,000 pounds of UF_6 was released to the environment when a 14-ton cylinder dropped from a transporter and ruptured, emptying its contents. Releases resulted from cascade system upgrade work, equipment failures, improper valve lineups, trap overloading, and maintenance activities; cylinder handling and movement; cylinder connection and disconnection activities at feed, withdrawal, and sampling stations; and process equipment disassembly during shop maintenance activities.

The documentation of releases and subsequent evaluations and investigations at PORTS were extensive, including technical department engineering reports, release reports, production memoranda to file, Goodyear Atomic Corporation and OR investigations, industrial hygiene and health physics department reports, and log books from the industrial hygiene and health physics, security, and fire departments. For releases greater than small puffs or wisps, analysis of the conditions, causes, and personnel exposures were analyzed to identify actions to correct causes and mitigate future events, identify personnel for special bioassays, and ensure proper survey, decontamination, and monitoring of work areas or the environs. These reports identified many employees who were exposed from these releases and required medical bioassay examinations. However, workers interviewed by the team recalled that for smaller releases (puffs), personnel were not always sent to the medical group for bioassay. Typically, after releases of UF_6 or F_2, workers directly involved or in adjacent areas would be required to provide urine specimens for bioassay to determine whether there was any internal intake and, if so, how much. If the bioassay indicated the presence of uranium or fluorides above certain limits, personnel were required to submit subsequent samples (called "recall") to monitor excretion rates until levels reached the initial threshold. If intakes were high, the person would be put on work restriction, limiting further exposure until levels returned to normal. If supervision or industrial hygiene and health physics considered that the person might have had a significant intake, the worker would be placed on work restriction immediately until the actual exposure could be determined by bioassay. The number of persons placed on recall for bioassay was as high as 40 or more per month in the 1950s, but declined significantly to a few persons per month in the 1980s.

While the documented injuries or illnesses linked directly to releases or exposures to UF_6 and F_2 were relatively infrequent, many workers did receive treatment for burns and respiratory ailments. A tails withdrawal release resulted in traumatic injuries requiring a five-day hospital stay for one worker and lengthy work restriction for another. Several worker compensation cases in the late 1950s and 1970s resulted in compensation for workers exposed to HF and other toxic materials at PORTS. Some workers had extremely high intakes of uranium detected by bioassay or in-vivo testing that put them on work restriction for months or years. For example, in 1965 ten employees sustained lung exposures greater than one-half the permissible level, and eight were reported to the AEC as overexposures in accordance with AEC regulations. In addition, a worker who had a massive intake of UF_6 in 1973 was still excreting uranium six months later, and two workers in 1965 were exposed to uranium levels high enough that, as late as 1973, in-vivo testing showed greater than 50 percent of the maximum allowable body burden for uranium. Finally, one worker, still living, was put on permanent restriction in 1981, and his in-vivo monitoring before his 1985 retirement still showed high uranium readings in his lungs.

In the first few years of operation, many routine bioassays (scheduled and not the result of known events or potential exposures) came back positive. Each was investigated for source, and actions were taken where warranted. Although the response was laudable, the fact that so many routine bioassays revealed unexpected intakes indicates a lack of adequate awareness and control of contamination and/or inadequate understanding of the required response to exposure, or possible exposure. There was evidence that industrial hygiene and health physics department recommendations for engineering controls (i.e., added ventilation or containment) or cleanup of contamination were often implemented.

As better equipment was installed, major system upgrade work ended, and operational practices improved, the number and quantity of UF_6 releases decreased significantly. The total yearly number of documented releases also fluctuated with the amount of enrichment or maintenance activity, dropping from about 160 in the 1950s to 50 in the 1960s when the Plant operated at reduced power levels, 85 in the 1970s, and back to 120 in the 1980s. However, the average size of the releases decreased markedly in the 1980s, many less than one gram (an amount that might not have been reported in the early years). About 45 UF_6 releases over ten pounds occurred in the first six years of operations, with only six in the 1980s. The AEC directed several concerted attempts to reduce UF_6 releases in the 1970s: in 1974 after several big releases in succession, and in 1978 after the 14-ton cylinder drop accident. Following several significant releases from Plant vents in the mid-1980s, continuous monitors were installed to measure releases, piping and procedures were modified to prevent inadvertent venting, and training and management direction were provided to maximize the return of UF_6 to the cascade. Although many releases were due to equipment failures, the preponderance of events and unnecessary exposures and contamination spread were caused by personnel errors, including failure to follow procedures related to operations or maintenance, failure to wear proper personal protective equipment, and improper emergency response to the release. Logbook entries by health physics technicians and event reports from the early 1980s noted repeated instances where personnel performing normal work activities or exposed in releases were not wearing respirators as required or were observed re-entering work areas after a release before required surveys and air monitoring were performed.

The spread of contamination to the environment and exposure to personnel away from the release point is affected by many things, such as release location, openings in the buildings, ventilation, immediate response by workers, weather conditions, quantity, and assay of material released. UF_6 gas is hydrolyzed with moisture in the air into HF gas and solid UO_2F_2, most of which drops quickly from the vapor cloud. HF gas is highly corrosive, and exposure can result in burns to exposed skin and the respiratory tract. Both HF and UO_2F_2 are environmental contaminants; HF primarily reacts with vegetation and soil, and highly soluble UO_2F_2 is washed into low points on the ground and into waterways. Many other events involving spills of various hazardous materials have had negative impacts on the environment. Spills of antifreeze, gasoline, sodium hydroxide, PCB oils, TCE, chromates, and lithium hydroxide, as well as UF_6 and F_2, have affected plant life and fish and contaminated waterways both on and off site. Section 4 of this report further discusses the effects of releases on the environment and monitoring programs for accidental releases.

The only work-related fatalities at PORTS identified by the investigation team resulted from several construction accidents in the 1950s and one in the 1980s. Other significant events that did not involve the release of hazardous materials or injury to personnel were not reviewed by this investigation.

Cleanup of March 1978 Cylinder Drop

2.5 Worker Safety and Health Programs

Programs for worker safety and health were in existence from the beginning of Plant operation. Initial training classes for workers included the theory and protective actions for working with radioactive and hazardous materials. *Guide to Safety* handbooks including information on respirators, radiation, and industrial safety and industrial hygiene hazards and controls were developed and given to employees as early as 1955, but were infrequently updated. There were policies and procedures that addressed the radiological protection of workers. Personal protective equipment was provided and was available to workers and in work areas where hazards were greatest and protection was deemed necessary, although availability and quality were variable. The amount of formal training given to employees diminished after startup, and much of the knowledge concerning both operations and hazard communication and controls resulted from on-the-job training of new workers by more experienced personnel and supervisors. In later years, health and safety training was often given directly only to supervisors, who then trained the hourly workers, typically through monthly safety meetings. There appeared to be little effective oversight of safety meeting content or other supervisor training activities by Plant management or safety and health organizations.

The medical group, part of the Industrial Relations Division, initially administered the industrial safety, industrial hygiene, and health physics programs, with separate sections for each. In 1957, industrial hygiene and health physics were combined into a separate department and later combined with environmental management under a Superintendent of General Safety and Environmental Management. In 1977 these organizations achieved more autonomy under a newly created Technical Services group, headed by an Assistant General Manager. Documentation indicates that Goodyear Atomic Corporation had a sophisticated occupational health program providing comprehensive medical examinations for employees, including physicals and typical laboratory testing of vision and hearing. The industrial safety and industrial hygiene and health physics staff was actively involved in responding to, evaluating, and making recommendations for corrective actions for accidents and events. The medical group administered the bioassay and in-vivo monitoring programs as well as radiological, chemical, and environmental sampling and monitoring. Increasing concerns and apparent weaknesses in the occupational medicine program were reflected in audits, AEC appraisals, safety committee meetings, and union negotiations in the 1970s. Issues with staffing, quality of service, and program management continued into the 1980s.

Many of the details on controls for radiological, industrial and chemical hazards in the workplace for routine operations were identified in work procedures, hazardous work permits, and electrical work permits issued for specific tasks, such as system entries or maintenance. In 1970 the OSHA standard drove introduction of additional permits for lockout/tagout, welding, and confined spaces. Responsibility for worker safety and health protection was delegated to line supervisors, and the role of the health and safety organizations was to provide support and advice. It was not until the 1970s that the health and safety staff had direct input or authority to review procedures and permits and took on a stronger role in hazard identification and control, and compliance inspections. Safety committees and union safety representatives were active in identifying safety and health issues, but less effective in consistently bringing about satisfactory resolution. The union grievance process was often used to identify health and safety concerns, a process that again achieved mixed results.

The focus of the industrial safety program until the 1970s was on safety awareness, not on compliance or hazard analysis. Safety goals were set and statistics on accidents and occupational illnesses were kept and reported to the AEC as required. Staffing for the safety effort varied from about eight engineers in the 1950s to two during the 1960s, when production and Plant worker populations were significantly reduced. In the 1970s, with new OSHA standards, new construction, and increased production activities, the safety organization became much more involved in hazard identification and controls. In 1973, OR conducted a comprehensive safety compliance review against the new OSHA regulations, resulting in extensive upgrading of safety systems and controls.

The evolution of awareness and the application of protection and controls for significant non-radiological hazards, such as asbestos and PCBs, essentially paralleled that of the regulatory bodies and general industry. Air monitoring of hazardous job sites existed from Plant startup, and health physics personnel monitored air and surface contamination in work areas and recommended revisions to existing engineering controls or personal protective equipment, if deemed necessary. Identification of asbestos and PCBs as hazards did not emerge until the late 1970s. Procedures for the handling, storage, and disposal of PCB-contaminated oils were in place in 1977, and no formal asbestos program existed until 1980.

Workers were also exposed to a variety of toxic gases, solvents, and metals at PORTS. The hazards associated with a number of these materials were known in 1955, and precautions were included in safety bulletins and manuals. It is not clear that work procedures always addressed proper personal protective equipment or controls. Surveys and instructions from industrial hygiene appeared to be reactive to events rather than proactive. Instrument

Basic Radiation Definitions

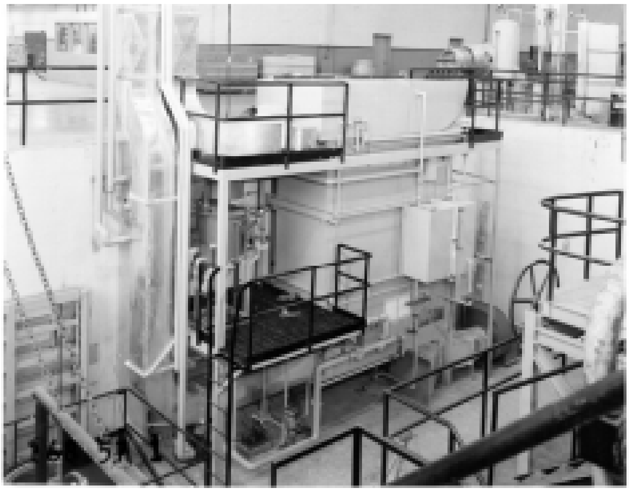
Employees at PORTS could encounter four types of radiation during their employment: alpha, beta, gamma, and neutron.

Alpha particles *are heavy, charged particles emitted from the nucleus of an atom and are primarily an internal exposure hazard through inhalation or ingestion. Because of their relative size and energy, alpha particles are much more hazardous than beta particles or gamma rays inside the body. Uranium, neptunium, and isotopes of plutonium are alpha emitters.*

Beta particles *are charged particles emitted from the nucleus of an atom and may be either internal or external exposure hazards. Enriched uranium, technetium-99, and isotopes of plutonium produce beta particles.*

Gamma rays (and x-rays) *are penetrating forms of radiation produced during decay of radioactive materials and are an external exposure hazard. Isotopes of uranium, neptunium, and plutonium produce penetrating radiation in the form of either gamma or x-rays.*

Neutron radiation *is a particulate radiation resulting from nuclear reaction and is an external exposure hazard. The main sources of neutron exposures at PORTS are spontaneous fissions in* UF_6 *cylinders in cylinder storage yards.*



X-720 Degreasing Apparatus

technicians and chemical operators frequently worked around mercury used in numerous process instruments and chemical traps. TCE was used in large quantities as an effective degreaser and general cleaning agent; its use was discontinued in the late 1970s, and bulk quantities of the solvent were removed. However, PORTS had lingering problems with continued use of residual supplies of TCE. A special industrial hygiene survey in 1986 identified TCE levels above the Threshold Limit Value in X-326. There was also limited evidence of incidental use of beryllium at PORTS. These may have been incidental machining of beryllium copper-alloy piping components. Tools plated with beryllium were also used. Beryllium was also used as a coating on early fluorescent light bulbs and was contained in some welding rods. Beryllium was routinely sampled in the environment in the early 1990s, and detectable beryllium concentrations above background were identified in several areas at PORTS.

In the 1950s and 1960s, the health physics staff provided exposure monitoring services, recommended training and protective measures to supervisors, maintained exposure and radiation measurement records, administered the bioassay program, investigated air samples and personnel exposures that were outside of specifications, studied Plant hazards and needed controls, and performed Plant environmental monitoring. However, the size of the health physics staff (i.e., one or two health physicists and approximately five technicians doing both industrial hygiene and health physics surveys) during the first 20 years of operation limited the amount and effectiveness of monitoring and control for the activities of up to 2,500 people in numerous and diverse hazardous work environments. While line supervision had always been responsible for implementing recommended controls and protective measures, supervisory oversight and enforcement of personal protective equipment use were inconsistent. Non-compliant personal protective equipment use by workers can in part be attributed to the pressures to maintain normal process operations, a lack of knowledge and full understanding of the risks involved and why the protection was needed, and the physical discomfort and vision impairment associated with wearing personal protective equipment, such as respirators, in hot, dirty environments.

Most radiological work controls, including time limits on worker exposures to uranium, were based on the assumptions that the primary risks for uranium exposure were chemical, not radiological, and that uranium was soluble and would be eliminated by the body quickly through the kidneys. Thus, inhalation protection was encouraged, and bioassay urinalysis was employed from PORTS startup to monitor intakes by workers who might be exposed to uranium or fluoride materials. However, the solubility assumption may not have been appropriate for areas such as the feed and oxide conversion plants and grinding and welding operations, where small particle sizes and relatively insoluble uranium compounds were present. Limitations were established for uranium and fluoride levels and excretion rates, and work area restrictions were placed on workers with elevated uranium until concentrations returned to acceptable levels. However, urinalysis would not detect intakes of insoluble uranium reliably and at sufficient sensitivity. In the early 1960s, in-vivo radiation monitoring for insoluble radionuclides by lung counting was initiated, first by sending workers to Fernald or Oak Ridge, and later using a mobile counter periodically sent to PORTS from Oak Ridge. However, lung-counting methods were not sufficiently sensitive and were only effective for assessing relatively large intakes. In-vivo monitoring was performed primarily on a sampling basis and, in the early years, typically relied on volunteers from work areas subject to uranium exposure. Film badges were used from the beginning of Plant operation to monitor personnel exposures to beta and gamma radiation; they were assigned based on expected exposure in work areas. Until the mid-1980s, extremity monitoring was not employed, although a number of activities presented opportunities for extremity exposures significantly higher than monitored whole body exposures. Some components that required significant manual handling had contact radiation levels above 1 rem/hour, and such a dose rate could quickly result in overexposures.

PORTS established conservative local limits as Plant Allowable Limits (PALs) for surface contamination control, compared to other gaseous diffusion plants and regulatory limits. Industrial hygiene and health physics department surveys were conducted both routinely and for specific work activities, and after events or condition changes. Portable survey instruments were available in many work areas for use by workers and supervisors, although the frequency of use and proper techniques were not monitored or enforced. Fixed hand and foot monitors were in place for some consistently contaminated areas. However, pervasive contamination problems persisted into the 1980s. It was not until 1991 that clothing and whole body monitors for exiting radiological areas were instituted Plant-wide. Respiratory protection was employed to minimize personnel exposures to airborne radiological and chemical hazards. The enrichment of high-assay uranium compounds (over 20 percent) complicated personnel protection efforts due to the higher specific activity of highly enriched uranium. In the 1950s and 1960s, the respiratory protection program principally utilized dust masks and the Army assault mask. In the late 1960s and early 1970s, better respirators were obtained, individual respirators were fitted and assigned to individuals, fit testing requirements were instituted, and additional respiratory protection training was performed. Observations by the industrial hygiene and health physics department, investigations of releases, and OR health and safety appraisals in the 1960s and 1970s collectively indicated chronic problems with workers' failure to wear respiratory protection where required and poor enforcement of respiratory requirements by line supervision. Bioassay and in-vivo monitoring results reflect the results of an inadequate respiratory protection program in the first two decades of Plant operation.

2.6 Waste Management

PORTS has generated large quantities of both hazardous and non-hazardous waste materials that have required storage, treatment, or disposal. These materials include construction waste, general office and kitchen trash, classified equipment, highly toxic or caustic chemicals, contaminated tools and clothing, and various radioactive substances. External requirements, treatment and disposal methods, and the overall waste management program evolved over time, resulting in more sophisticated, rigorous, and environmentally friendly processes for handling solid, hazardous, and radioactive wastes. However, as discussed below, the progression of waste handling practices and the closing of disposal locations have resulted from failures to comply with previously established guidelines and requirements for controlling hazardous and radioactive wastes.

Initially, the handling and control of hazardous waste were the responsibility of the Chemical Operations Division. Gradually, the Industrial Hygiene and Health Physics department assumed environmental compliance responsibilities. In 1986, a waste management division was created, and in 1991 this organization was elevated to being a department. Formal procedures were established as early as 1955 detailing guidelines for handling, storing, and disposing of wastes. In 1970, the position of Pollution Coordinator was created and a Pollution Control Committee was formed to establish and oversee policy. In 1979, formal procedures and associated training were developed for the use of Plant landfills, and, in 1981, additional procedures were implemented for operating the sanitary landfill, including a ban on burning of wastes. In 1990, all waste management programs and organizations were integrated, leading to a major overhaul of waste management procedures.

Starting with groundbreaking in 1952, construction wastes were disposed of in a landfill created south of the Plant, which operated until 1968. In 1998, it was closed in accordance with State of Ohio EPA and Resource Conservation and Recovery Act (RCRA) requirements. In 1982, X-734A was created as a new construction spoils area, but was closed in 1985 because requirements for excluding hazardous substances had been continuously violated. This former spoils area is currently undergoing RCRA closure. Subsequently, construction spoils were sent to the X-735 sanitary landfill. However, the sanitary landfill had to be partially shut down in 1990 when an external inspection found improper disposal of rags containing RCRA-regulated solvents. In 1998, when a new landfill was needed to meet stricter environmental controls, DOE closed X-735 and shipped non-radioactive solid wastes off site to the Pike County landfill.

Before hazardous wastes were regulated, most liquid wastes were processed in various pits and lagoons prior to discharge. Therefore, minimal quantities of waste were containerized for disposal.

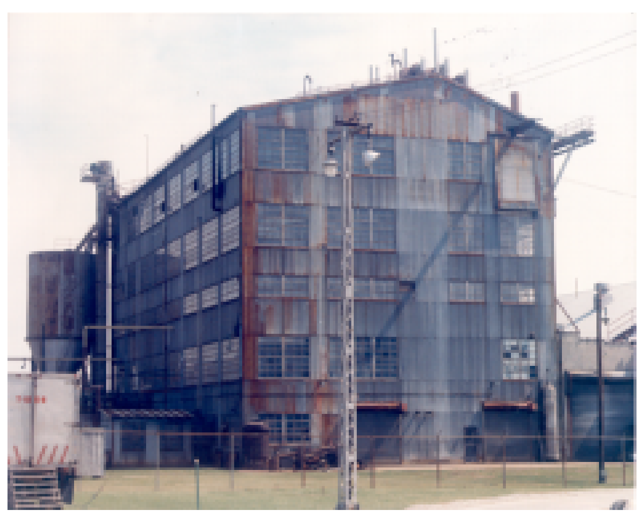
Burning was also used extensively at PORTS to dispose of oily wastes until the mid-1970s. In the early 1970s an experimental program of oil biodegradation was established in two plots near X-600, identified as X-231A and X-231B. Many thousands of gallons of solvent-contaminated oil, chlorinated solvents, and over 100,000 pounds of oil soaked fuller's earth absorbent were tilled into the ground at X-231A until it was closed in 1977. X-231B operated until it was shut down in 1988 as part of a RCRA action after an Ohio EPA inspection identified significant problems and served DOE with a notice of intent to file suit for hazardous waste violations. Internal documents also reflected repeated problems with the controls on the process and management of the biodegradation program.

Large quantities of PCBs existed at the Plant, principally in electrical transformers and capacitors, but also as a contaminant in process building lubricating oils and ventilation duct gaskets. Although the industry and the AEC provided safety information concerning PCBs in 1972, the Plant did not issue specific guidance on the disposal of PCB-contaminated items until 1979 after Federal regulations were issued. Additional procedures were issued in 1983 addressing the handling of PCB waste when PCB-contaminated sludge was identified at the site sewage treatment plant. However, PORTS had continuing problems managing PCB-contaminated materials; in 1988 DOE noted that controls were insufficient to comply with commitments to the EPA, and in 1989 the DOE Tiger Team identified a lack of formal Plant procedures to implement PCB cleanup standards. These concerns resulted in the formation of PCB Implementation Teams. Currently PCB waste, regulated under the Toxic Substances Control Act (TSCA), is being stored in DOE Material Storage Areas in the process buildings.

A similar process occurred for RCRA regulated waste. After an initial aggressive approach to compliance, DOE determined that RCRA regulations did not apply and a self-regulated approach was taken. After an agreement was reached with EPA in 1987 on RCRA applicability, PORTS took several actions to return to compliance. In the early 1990s, X-7725 was upgraded to a compliant permitted RCRA facility and currently houses all stored mixed and hazardous wastes, except for some enriched mixed and radioactive wastes that are stored in the X-326 L Cage area to provide additional security.

Low-level radioactive wastes were buried in the X-749 contaminated material disposal facility starting in the late 1950s. This continued to be the primary disposal site for low-level waste until operations ceased in 1992 at the direction of the Ohio EPA. Equipment and scrap were generally subjected to decontamination prior to disposal, primarily to salvage residual uranium for re-feeding to the process. Hundreds of tons of material were disposed of in X-749 just before shutdown. A 1976 report determined that unsealed chemical trap residues disposed of in X-749 during the previous 20 years contained very water-soluble technetium. Subsequently this material was sealed prior to disposal.

Right after Plant startup, two oil-fired incinerators were used for classified burnables and uranium-contaminated wastes, including waste oil. (Waste oil was also buried in salamanders near Building X-705.) Little documentation exists concerning these incinerators, but 1962 OR assessment results were favorable. In 1971 these incinerators ceased operation after Goodyear Atomic Corporation determined that they were inefficient and did not meet smoke or particulate emission standards. A new incinerator was built in 1971. Ash was sampled for salvageable uranium and sent to the recovery process or disposed of in X-749. Again, there were problems with operation of the new incinerator. Until an enclosure was built in the late 1970s, contaminated burnables and ash were scattered by winds. Severe smoking due to plastics disposal and several events involving smoke incursion into adjacent buildings caused medical problems for occupants. In the mid-1980s, reports indicated improper incineration of materials as a result of unclear operating limits. DOE subsequently shut down the incinerator, and the State of Ohio revoked its registration. The facility was finally closed under RCRA authorities in the 1990s.



Huntington, West Virginia, Plant

In 1978, the DOE INCO nickel plant in Huntington, West Virginia, was dismantled, transported to PORTS, and buried in the X-749A classified landfill due to security concerns and the fact that some of the INCO plant materials were somewhat contaminated with uranium, nickel carbonyl, and asbestos.

Large volumes of scrap and surplus materials generated at PORTS were collected and stored onsite. Much of this material was sold at public auctions from the 1950s into the 1980s. These activities led to documentation of many health and safety concerns, including the failure to consistently segregate contaminated and clean materials, insufficient industrial hygiene and health physics staff to perform pre-sale surveys, inadequate controls on buyer access to scrap yards prior to sale, and surveys indicating that highly contaminated items were in the scrap yards. Therefore, it is possible that some contaminated materials were sold to the public, and buyers may have been contaminated during the auction process.

2.7 Air and Water Emissions

Routine, accidental, diffuse, fugitive, and planned emissions of radioactive materials and fluorine to the environment have occurred at PORTS since the beginning of operation in 1954. Site records and subsequent analysis estimated that over 23,000 pounds of uranium and 27 curies of technetium had been released into the atmosphere from 1954 to 1993. Workers complained of fluorine emissions from X-342 into the 1980s. Environmental monitoring in the early years consisted of liquid effluent sampling and sampling of vegetation and soils after identified accidental releases. Air sampling, both onsite and offsite, did not begin until the mid-1960s. Although known to exist in process systems since the early 1960s, significant amounts of technetium were not detected until 1975 when a marked increase in beta and gamma activity was measured. This increase in technetium emissions may be linked to disturbances caused by process equipment changeout and maintenance activities.

Vent emissions at PORTS were not monitored continuously until the mid-1980s. Grab sampling and radiation detectors in the vent line piping (called space recorders) provided some means of monitoring and calculating releases of uranium and fluorine. However, the unreliability of space recorders and the inaccuracy of grab sampling when compared to continuous monitoring indicate that emissions may have been underestimated. An event in 1985 released over 110 pounds of uranium into the atmosphere from the X-333 wet air evacuation vents over a period of 21 days when traps were overloaded and operators ignored space recorder alarms. Piping and valve configurations associated with process building vents also provided opportunities for operator error or intentional bypassing of traps and monitors, resulting in unmonitored releases to the atmosphere. An atmospheric vent committee in 1985 recommended that continuous monitors be installed on a number of vents. The feed production plant also contributed significant amounts of radioactive emissions to the environment from its operations between 1958 and 1962. Fluorine releases from the X-342 fluorine plant stack have been frequent and have resulted in numerous complaints from workers in the area, especially during temperature inversions, fog, or rain, when the vented gases are forced to ground level.

Accidental releases of UF_6 have contributed a significant portion of the estimated emissions at PORTS. The 1978 cylinder rupture event contributed almost 50 percent of those estimated emissions. Diffuse and fugitive emissions were not typically calculated until 1994, and contamination found later on roofs, grounds, and work areas reflect notable unmonitored releases. The oxide conversion facility in X-705E was the source of known fugitive emissions during its operation between 1959 and 1978. Planned releases, including venting of purge gases from the cascade cells while obtaining "negatives" for maintenance, also contributed an unknown quantity of radioactive emissions to the atmosphere.

Liquid effluents from Plant operations were typically released to the environment via drains to sanitary sewers and the cooling tower blowdown system, discharges to holding ponds, or runoff to the storm water drainage system. Discharges other than those treated or held up prior to release flowed to site outfalls and the east and west drainage ditches to Little and Big Beaver Creeks and then to the Scioto River. Effluents from the two main ditches and the south holding pond have always been routinely analyzed for radioactivity, and cooling tower blowdown has been monitored for chromium prior to discharge to the river. In 1970 the Ohio Pollution Control Board established standards for public water supplies. The Plant environmental management structure, procedures, and monitoring programs were strengthened to ensure compliance with these new regulations. In 1976, a chromium reduction facility was built for treating blowdown cooling water before discharge to the Scioto River.

The X-705 decontamination and cleaning activities have always generated the most significant liquid radiological effluent at PORTS. Decontamination solutions and other wastewater were discharged to the X-701B holding pond at rates as high as 50,000 gallons a month until the pond was closed in 1988. Other waste chemicals from laboratories in X-705, and the X-700 cleaning solvents, such as TCE, also went to the holding pond. When the holding pond was closed, a recirculation system for the treated water was installed in X-705 and a micro filtration system was added to process all waste solutions prior to discharge.

In 1975, when the beta-gamma activity in the east drainage ditch increased markedly, PORTS determined that it resulted primarily to technetium from X-705, via the X-701B holding pond. From 1974 to closure in 1988, lime was added to the influent of X-701B, causing a large sludge buildup that necessitated annual dredging and disposal. Accidental spills of TCE and other solvents, PCBs, sodium hydroxide, ethylene glycol, gasoline, and UF_6 have caused damage to the environment, including several significant fish kills in surrounding creeks, one of which resulted in restitution payments to the state.

2.8 Management and Oversight

Although, the AEC, ERDA, or DOE have had a nearly continuous site presence at PORTS, oversight of ES&H performance was not rigorous or proactive for much of PORTS history. This oversight was sometimes effective when vigorously exercised; however, consistency and follow-through on corrective actions were often lacking. On numerous occasions, the positions of management and labor differed widely, and resolution was accompanied by extreme measures, as evidenced by one unauthorized and six authorized strikes between 1954 and 1997. While economic issues were common to most strikes, safety and health were an important element in three of these seven actions. Workers compensation claims, which began to appear in the early 1950s, reveal discord between management and labor. Interviews with past and present employees and review of records indicate that there were allegations by employees that management would go to great lengths to deny or avoid compensation claims, including being untruthful and pursuing legal loopholes to avoid accountability. Collectively, the number of grievances filed, workers compensation claims submitted, and alleged acts of retaliation committed provide further support that management and labor relations were strained. From 1954 through 1993, it is estimated that more than 17,000 union worker grievances were filed, addressing a variety of issues in addition to safety and health, including work jurisdiction, discipline, overtime, work rules, and benefits.

SIGNIFICANT PORTSMOUTH PLANT MILESTONES AND EVENTS – 1952 TO 1999

August 1952	*Portsmouth selected as site for new gaseous diffusion plant*
September 1952	*Goodyear Tire & Rubber Company selected as the plant operator; Goodyear creates Goodyear Atomic Corporation to operate the Plant*
November 1952	*Groundbreaking and start of construction*
June 1953	*Portsmouth Training School opens*
September 1954	*First production cells go on line*
November 1954	*Portsmouth Oil, Chemical, and Atomic Workers Union (OCAW) established*
January 1955	*Goodyear Atomic starts 40-hour Basic Supervisional Training Program*
June 21, 1955	*United Plant Guard Workers established at Portsmouth*
November 1955	*First burial in classified disposal yard — X-749A*
March 1956	*Plant construction completed*
October 3-4, 1956	*Unauthorized walkout by 48 workers in X-700; later joined by 260 other workers*
1957	*Initial oxide conversion begins in X-705E*
1957	*Hearing conservation programs established*
May 10-16, 1957	*OCAW strikes*
1958-1962	*Feed production plant operates*
May 2-20, 1969	*OCAW strikes*
1970	*OSHA Act becomes law*
1972-1983	*CIP/CUP activities conducted*
May 2-August 8, 1974	*OCAW strikes*
January 1975	*NRC and ERDA assume regulatory responsibility for AEC functions*
August 28-December 13,1976	*OCAW strikes*
October 1977	*DOE assumes regulatory responsibilities from ERDA*
March 1978	*Emergency declared following cylinder rupture during which over 21,000 pounds of material are lost*
October 1978	*Oxide conversion placed in standby status and never operated again*
November 1978-April 1979	*Burial in X-749A of dismantled nickel plant and equipment from West Virginia*
1979	*Lithium relocation project completed*
May 3-December 15, 1979	*OCAW strikes*
1983	*OSHA Hazard Communication Standard issued*
July and November 1985	*EPA issues Findings of Non-Compliance with RCRA*
September 1986	*EPA and DOE sign Federal Facilities Compliance Agreement addressing 1985 RCRA violations*
November 1986	*Martin Marietta Energy Systems replaces Goodyear as the operating contractor*
September 1989	*EPA and DOE sign Administrative Consent Order (ACO) to ensure compliance with RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*
October-November 1989	*DOE conducts Tiger Team assessment of PORTS*
May 1990	*X-749 landfill closed*
December 1990	*Waste Management Division created*
June 1991	*Initiated shipment of waste oil to the Oak Ridge K-25 TSCA incinerator*
June 11, 1991-April 6, 1992	*OCAW strikes*
November 1992	*Energy Policy Act creates USEC to manage the Federal government's uranium enrichment enterprise*
July 1993	*USEC contracts with Martin Marietta Utility Services for operation and maintenance of enrichment plants*
June 1995	*Martin Marietta becomes Lockheed Martin following merger*
June 1995	*First shipment to USEC of Russian low enriched uranium derived from highly enriched uranium*
October 1995	*Ohio EPA approves PORTS Site Treatment Plan*
1996	*Completed decontamination and decommissioning of X-705A incinerator*
April 1996	*USEC Privatization Act is signed into law*
November 1996	*NRC grants certificate of compliance for enrichment operations*
March 1997	*Regulatory oversight of enrichment enterprise transferred from DOE to NRC*
June 1997	*EPA, Ohio EPA, and DOE sign ACO giving Ohio EPA regulatory authority for day-to-day activities*
1998	*In settlement with Ohio EPA and Ohio Attorney General, PORTS pays a $193,000 penalty related to improper storage of lithium hydroxide and uranium hexafluoride*
April 1998	*Bechtel Jacobs awarded DOE management and integration contract*
May 1999	*USEC takes over direct operation of all enrichment activities*